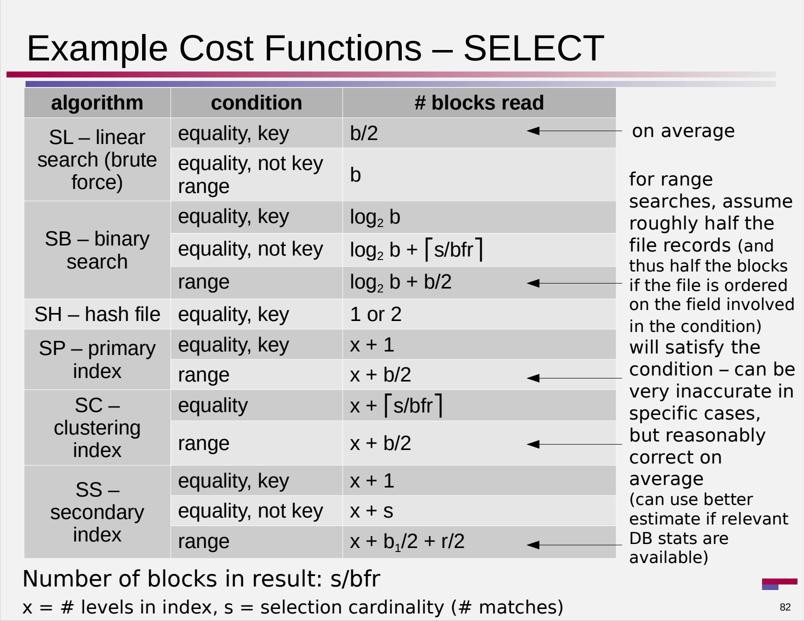


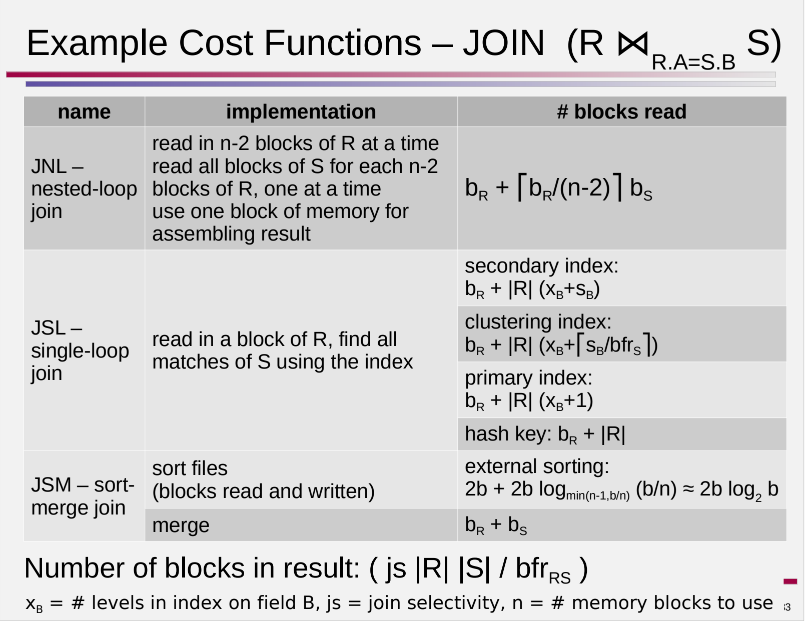
Example Cost Functions – SELECT

algorithm	condition	# blocks read
SL – linear search (brute force)	equality, key	b/2 ← on average
	equality, not key range	b
SB – binary search	equality, key	$\log_2 b$
	equality, not key	$\log_2 b + \lceil s/bfr \rceil$
	range	$\log_2 b + b/2$ ←
SH – hash file	equality, key	1 or 2
SP – primary index	equality, key	x + 1
	range	x + b/2 ←
SC – clustering index	equality	$x + \lceil s/bfr \rceil$
	range	x + b/2 ←
SS – secondary index	equality, key	x + 1
	equality, not key	x + s
	range	$x + b_1/2 + r/2$ ←

for range searches, assume roughly half the file records (and thus half the blocks if the file is ordered on the field involved in the condition) will satisfy the condition – can be very inaccurate in specific cases, but reasonably correct on average (can use better estimate if relevant DB stats are available)

Number of blocks in result: s/bfr

x = # levels in index, s = selection cardinality (# matches)

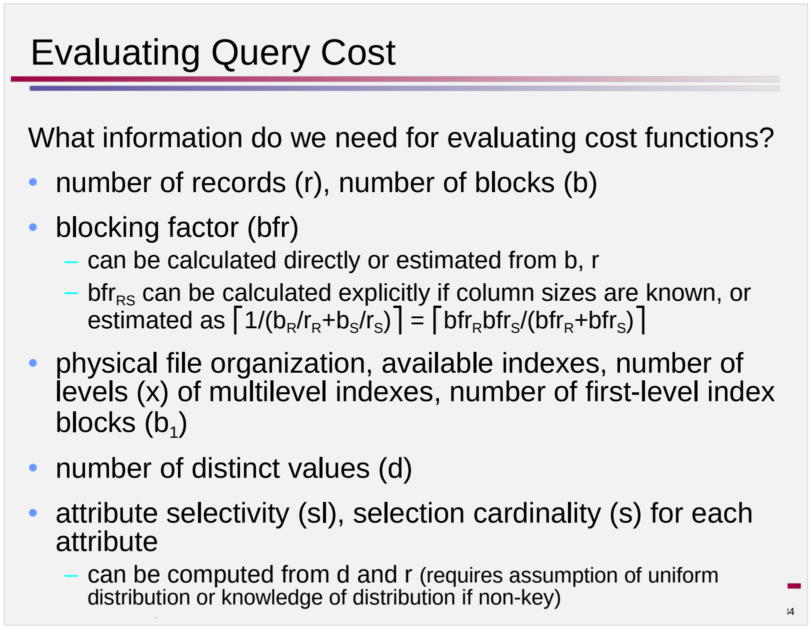


Example Cost Functions – JOIN (R $\bowtie_{R.A=S.B}$ S)

name	implementation	# blocks read
JNL – nested-loop join	read in n-2 blocks of R at a time read all blocks of S for each n-2 blocks of R, one at a time use one block of memory for assembling result	$b_R + \lceil b_R/(n-2) \rceil\, b_S$
JSL – single-loop join	read in a block of R, find all matches of S using the index	secondary index: $b_R + \lvert R\rvert\,(x_B+s_B)$
		clustering index: $b_R + \lvert R\rvert\,(x_B+\lceil s_B/bfr_S \rceil)$
		primary index: $b_R + \lvert R\rvert\,(x_B+1)$
		hash key: $b_R + \lvert R\rvert$
JSM – sort-merge join	sort files (blocks read and written)	external sorting: $2b + 2b \log_{\min(n-1,b/n)} (b/n) \approx 2b \log_2 b$
	merge	$b_R + b_S$

Number of blocks in result: (js |R| |S| / bfr_{RS})

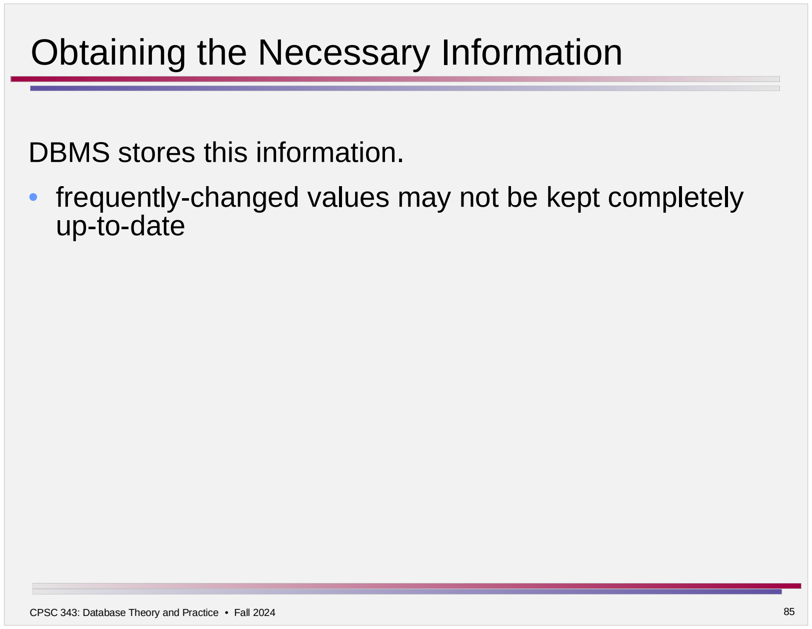
x_B = # levels in index on field B, js = join selectivity, n = # memory blocks to use



Evaluating Query Cost

What information do we need for evaluating cost functions?

- number of records (r), number of blocks (b)
- blocking factor (bfr)
  - can be calculated directly or estimated from b, r
  - bfr_{RS} can be calculated explicitly if column sizes are known, or estimated as $\lceil 1/(b_R/r_R+b_S/r_S) \rceil = \lceil bfr_R bfr_S/(bfr_R+bfr_S) \rceil$
- physical file organization, available indexes, number of levels (x) of multilevel indexes, number of first-level index blocks (b_1)
- number of distinct values (d)
- attribute selectivity (sl), selection cardinality (s) for each attribute
  - can be computed from d and r (requires assumption of uniform distribution or knowledge of distribution if non-key)



Obtaining the Necessary Information

DBMS stores this information.

- frequently-changed values may not be kept completely up-to-date

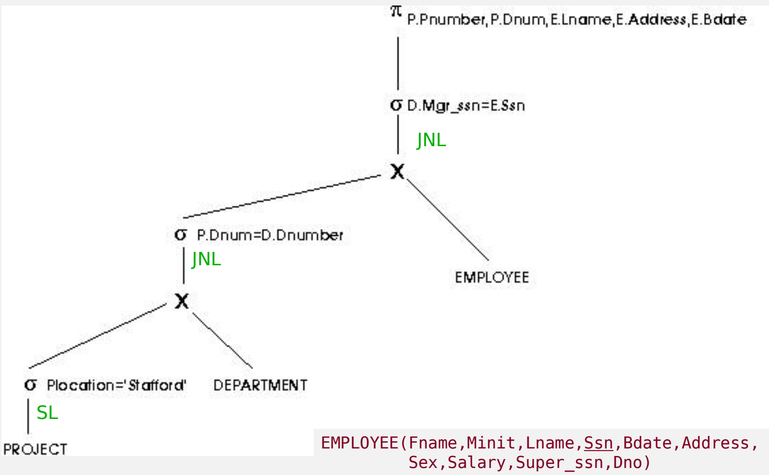
DB Stats

table	column	# distinct values (d)	low value	high value
PROJECT	Plocation	200	1	200
	Pnumber	2000	1	2000
	Dnum	50	1	50
DEPARTMENT	Dnumber	50	1	50
	Mgr_ssn	50	1	50
EMPLOYEE	Ssn	10000	1	10000
	Dno	50	1	50
	Salary	500	1	500
	Bdate		1945-01-01	1989-12-31

table	# records (r)	# blocks (b)
PROJECT	2000	100
DEPARTMENT	50	5
EMPLOYEE	10000	2000

index	# levels (x)	# level 1 blocks (b_1)
PROJ_PLOC	2	4
EMP_SSN	2	50
EMP_SAL	2	50

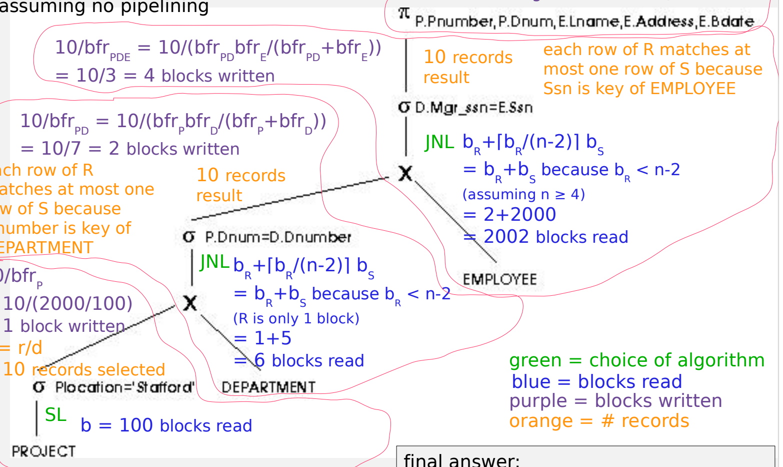
Cost of an Execution Plan – Plan 1



```
EMPLOYEE(Fname,Minit,Lname,Ssn,Bdate,Address,
         Sex,Salary,Super_ssn,Dno)
PROJECT(Pname,Pnumber,Plocation,Dnum)
WORKS_ON(Essn,Pno,Hours)
```

Cost of Plan 1

assuming no pipelining



4 blocks read
≤ 4 blocks written (depends on blocking factor of result)

$10/bfr_{PDE} = 10/(bfr_{PD}bfr_E/(bfr_{PD}+bfr_E))$
$= 10/3 = 4$ blocks written

10 records result

each row of R matches at most one row of S because Ssn is key of EMPLOYEE

JNL $b_R+\lceil b_R/(n-2)\rceil\ b_S$
$= b_R+b_S$ because $b_R < n-2$
(assuming $n \geq 4$)
$= 2+2000$
= 2002 blocks read

$10/bfr_{PD} = 10/(bfr_Pbfr_D/(bfr_P+bfr_D))$
$= 10/7 = 2$ blocks written

each row of R matches at most one row of S because Dnumber is key of DEPARTMENT

10 records result

JNL $b_R+\lceil b_R/(n-2)\rceil\ b_S$
$= b_R+b_S$ because $b_R < n-2$
(R is only 1 block)
$= 1+5$
= 6 blocks read

$10/bfr_P$
$= 10/(2000/100)$
= 1 block written
$s = r/d$
= 10 records selected

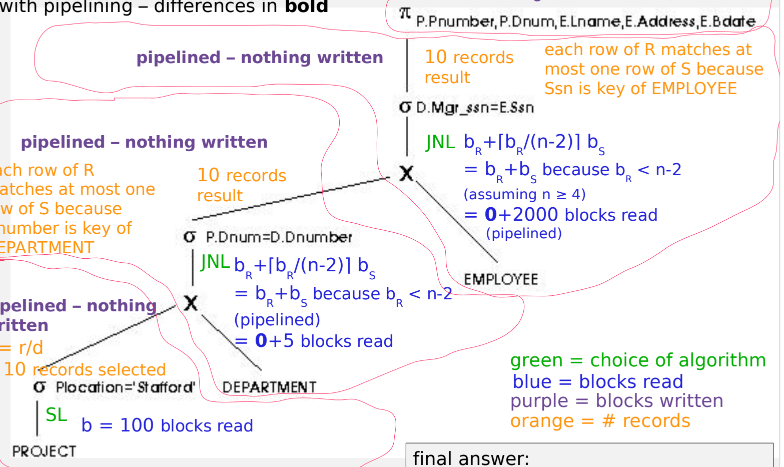
SL b = 100 blocks read

green = choice of algorithm
blue = blocks read
purple = blocks written
orange = # records

final answer:
2112 blocks read + ≤ 11 blocks written
= 2123 blocks

Cost of Plan 1

with pipelining – differences in **bold**



pipelined – nothing read
≤ 4 blocks written (depends on blocking factor of result)

pipelined – nothing written

10 records result

each row of R matches at most one row of S because Ssn is key of EMPLOYEE

JNL $b_R+\lceil b_R/(n-2)\rceil\ b_S$
$= b_R+b_S$ because $b_R < n-2$
(assuming $n \geq 4$)
= **0**+2000 blocks read
(pipelined)

pipelined – nothing written

each row of R matches at most one row of S because Dnumber is key of DEPARTMENT

10 records result

JNL $b_R+\lceil b_R/(n-2)\rceil\ b_S$
$= b_R+b_S$ because $b_R < n-2$
(pipelined)
= **0**+5 blocks read

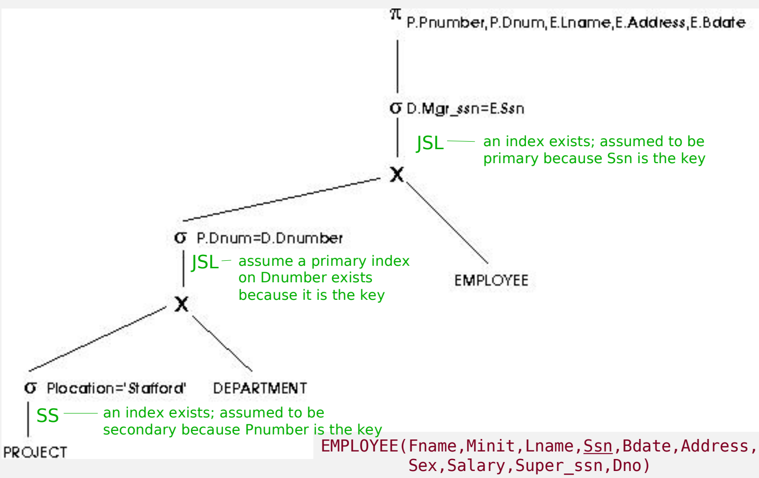
pipelined – nothing written
$s = r/d$
= 10 records selected

SL b = 100 blocks read

green = choice of algorithm
blue = blocks read
purple = blocks written
orange = # records

final answer:
2105 blocks read + ≤ 4 blocks written
= 2109 blocks

Cost of an Execution Plan – Plan 2



JSL — an index exists; assumed to be primary because Ssn is the key

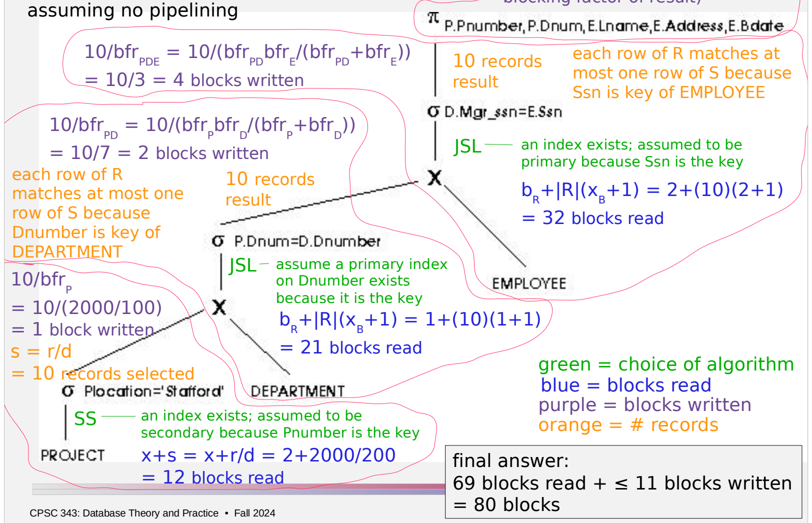
JSL — assume a primary index on Dnumber exists because it is the key

SS — an index exists; assumed to be secondary because Pnumber is the key

EMPLOYEE(Fname,Minit,Lname,Ssn,Bdate,Address,
Sex,Salary,Super_ssn,Dno)
PROJECT(Pname,Pnumber,Plocation,Dnum)
WORKS_ON(Essn,Pno,Hours)

Cost of Plan 2

assuming no pipelining



4 blocks read
≤ 4 blocks written (depends on blocking factor of result)

$10/bfr_{PDE} = 10/(bfr_{PD}bfr_E/(bfr_{PD}+bfr_E))$
$= 10/3 = 4$ blocks written

10 records result

each row of R matches at most one row of S because Ssn is key of EMPLOYEE

JSL — an index exists; assumed to be primary because Ssn is the key

$b_R+|R|(x_B+1) = 2+(10)(2+1)$
$= 32$ blocks read

$10/bfr_{PD} = 10/(bfr_P bfr_D/(bfr_P+bfr_D))$
$= 10/7 = 2$ blocks written

each row of R matches at most one row of S because Dnumber is key of DEPARTMENT

10 records result

JSL — assume a primary index on Dnumber exists because it is the key

$b_R+|R|(x_B+1) = 1+(10)(1+1)$
$= 21$ blocks read

$10/bfr_P$
$= 10/(2000/100)$
$= 1$ block written

$s = r/d$
$= 10$ records selected

SS — an index exists; assumed to be secondary because Pnumber is the key

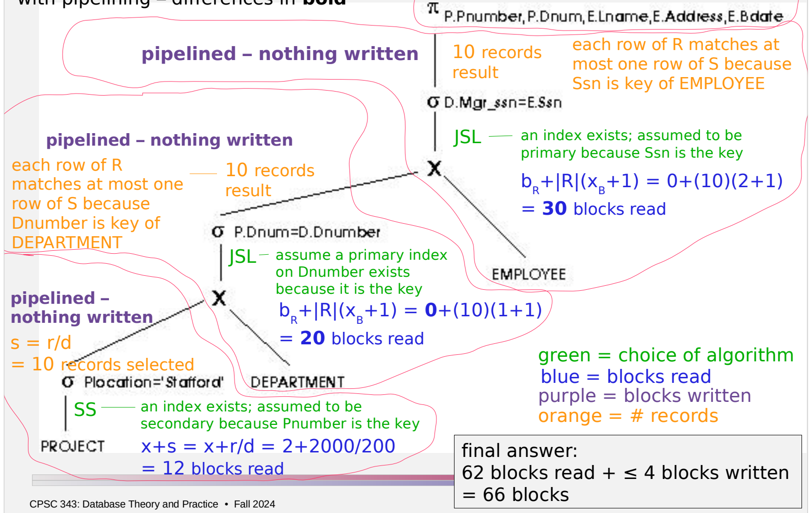
$x+s = x+r/d = 2+2000/200$
$= 12$ blocks read

green = choice of algorithm
blue = blocks read
purple = blocks written
orange = # records

final answer:
69 blocks read + ≤ 11 blocks written
= 80 blocks

Cost of Plan 2

with pipelining – differences in **bold**



pipelined – no blocks read
≤ 4 blocks written (depends on blocking factor of result)

pipelined – nothing written

10 records result

each row of R matches at most one row of S because Ssn is key of EMPLOYEE

JSL — an index exists; assumed to be primary because Ssn is the key

$b_R+|R|(x_B+1) = 0+(10)(2+1)$
$= \mathbf{30}$ blocks read

pipelined – nothing written

each row of R matches at most one row of S because Dnumber is key of DEPARTMENT

10 records result

JSL — assume a primary index on Dnumber exists because it is the key

$b_R+|R|(x_B+1) = \mathbf{0}+(10)(1+1)$
$= \mathbf{20}$ blocks read

pipelined – nothing written

$s = r/d$
$= 10$ records selected

SS — an index exists; assumed to be secondary because Pnumber is the key

$x+s = x+r/d = 2+2000/200$
$= 12$ blocks read

green = choice of algorithm
blue = blocks read
purple = blocks written
orange = # records

final answer:
62 blocks read + ≤ 4 blocks written
= 66 blocks